

# Spin Dependence in Electron — Atom Collisions

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This experimental project centers on the study of low energy electron-atom collisions in which the colliding particles are prepared in well defined states via laser optical pumping. This type of state resolved experiment provides substantially more information about the scattering process than measurements of the scattering cross section alone. Our primary interest is the direct observation of the role played by electron spin, through exchange and the spin-orbit interaction, in elastic and inelastic collisions. Additionally, we study the collisional transfer of angular momentum in inelastic scattering.

The experimental apparatus consists of crossed beams of electrons and sodium atoms, each of whose initial state is prepared through the use of optical pumping techniques. Both electrons and atoms are spin polarized either parallel or antiparallel to a quantization axis perpendicular to the horizontal scattering plane. The target atoms are pumped with circularly polarized laser light tuned to a particular hyperfine resonance line. The electrons are generated by photoemission in a GaAs polarized electron source with circularly polarized incident photons. The intensity of electrons scattered through some angle is measured with a channel electron multiplier as a function of the incident electron energy and initial state of the incident electrons and atoms. At each scattering angle, the scattering intensity is recorded for each of the four possible relative spin orientations of the incident beams. These intensities are combined into asymmetries, which are directly related to the normalized differences between the scattering cross sections for the various relative spin orientations.

Our measurements to date have included studies of both elastic scattering from ground state atoms, and studies of the 3S-3P transition. Our elastic studies are performed with the optical pumping region "upstream" in the atom beam, so the sodium atoms in the target region are spin-polarized in the ground state. The inelastic studies are done "superelastically," by placing the optical pumping region directly in the scattering center, and detecting only those electrons which de-excite the laser-excited atoms, thereby gaining the 2.1 eV excitation energy of the 3P state. Superelastic measurements are equivalent to the time inverse of coincidence measurements of the inelastic process, and hence yield the same sort of state-to-state scattering information.

The aim of this work is to provide as complete a set of data as possible on electron-sodium scattering at a few specifically chosen incident energies. Thus we are concentrating on generating sets of spin- and angular momentum-resolved elastic and superelastic results at the same energies (in fact, the superelastic data are obtained at an incident energies 2.1 eV lower than the elastic results, since they are "time-inverse" studies). Eventually, we hope to probe, in a state-selective manner, as many inelastic and superelastic transitions in the sodium atom as are feasible, so a complete comparison with *ab initio* calculations can be made.

In previous years, we have measured elastic scattering at 54.4 eV, and superelastic scattering at 52.3, 17.9 and 2 eV. This year has been spent for the most part on elastic scattering. To accompany the earlier 17.9 eV superelastic results, we have measured the elastic spin asymmetry at 20 eV incident energy, shown in Fig. 1. The spin asymmetry is defined as "antiparallel" minus "parallel" intensities divided by the total intensity, and represents the normalized difference between singlet and triplet scattering cross sections. The curve shows that the asymmetry

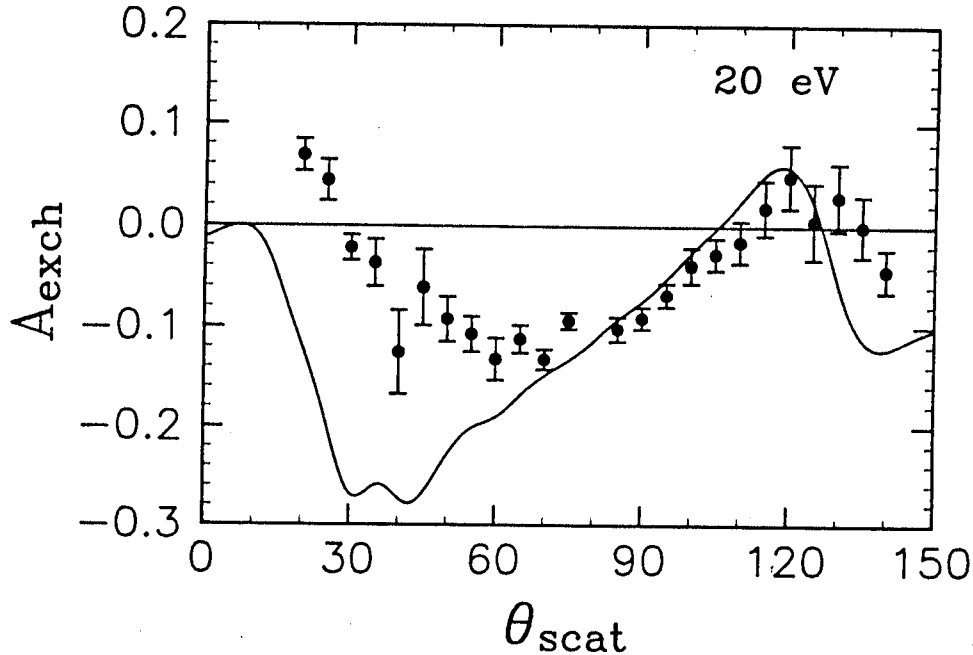


Figure 1: Elastic spin asymmetry vs. scattering angle. (•) experiment; (—) theory (D.H. Oza, Phys. Rev. A **37**, 2721(1988)).

is quite large in magnitude and negative in sign over most of the angular range. A value of  $-1/3$  corresponds to pure triplet scattering, so it appears that the triplet cross section is quite dominant over the singlet at most angles. The solid line in the plot is a 2-state close-coupling calculation by Oza, which, though qualitatively in agreement with experiment, shows some significant differences.

In previous elastic measurements at 54.4 eV, we obtained the surprising result that spin-orbit and exchange effects can be of the same magnitude in as light a scattering target as sodium. This raises the possibility that a “joint” asymmetry may exist, consisting of the difference between scattering from spin “up” and “down” atoms with unpolarized electrons. This asymmetry, predicted but never observed, is zero if either the spin-orbit effect or exchange alone is present, but can be non-zero if both are significant. We have conducted a systematic search for this joint asymmetry at incident energies of 20, 54.4, and 70 eV, and the results are shown in Fig. 2. 70 eV was chosen as an energy where the cross section has the deepest minimum, so any small effect would be more visible. We have shown that the “joint” asymmetry is smaller than 1% at all the energies and angles that were measured, and hence it is unlikely that this is a significant effect in sodium.

Current efforts are concentrated on measuring elastic scattering at 10 eV incident energy, combined with superelastic measurements at 7.9 eV. The next step is to measure elastic scattering below the ionization threshold, specifically at 4.1 eV to go with the earlier superelastic results at 2.0 eV. Other energies below the ionization threshold will then be probed, since dramatic effects can be expected in this energy region. In the coming year, we also expect to replace our retarding field energy analyzer on the electron detector with a hemispherical analyzer, which will enable us to probe other inelastic transitions in sodium.